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A SURVEY OF POPULATION CHARACTERISTICS FOR RED DRUM AND SPOTTED SEATROUT IN LOUISIANA

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ABSTRACT Red drum and spotted seatrout stocks were sampled from seven separate study areas along the Louisiana coast and from one estuarine area in Texas, with additional intensive temporal (monthly) and microgeographic (range of salinity regimes) samplings being carried out in one Louisiana study area. Condition coefficients, which did not appear to be affected by salinity regimes within the microgeographic sampling area, varied significantly according to study area, with Texas fish showing significantly lower condition coefficients than Louisiana fish. Von Bertalanffy growth equations were fitted and annual mortality rates were estimated to obtain preliminary estimates of yields, population numbers, and densities of these species in Louisiana.

INTRODUCTION

The popularity of red drum, *Sciaenops ocellatus* (Linnaeus), and spotted seatrout, *Cynoscion nebulosus* (Cuvier), as game and commercial fish on the Louisiana coast has resulted in increasing tension between sports fishermen and commercial fishermen, and caused concern that populations of these species in Louisiana may be declining (Perret et al. 1980). Other Gulf coast states, facing similar controversies, have recently enacted, or are considering enactment of laws restricting or banning commercial fishing for these species.

Assessment and effective management of such fish stocks generally requires reasonable estimates of population parameters such as natural mortality, fishing mortality, density, growth rates, and recruitment. Length-weight relationships and condition coefficients may also provide useful insights concerning the relative well-being of fish stocks in different areas (Bagenal and Tesch 1978).

The primary purpose of this study was to evaluate the status of red drum and spotted seatrout populations in Louisiana, to supplement the growing body of data on the biology of these species in the northern Gulf of Mexico (Overstreet 1983a and 1983b), and to provide estimates of the various population parameters needed for more effective management of these important species in Louisiana.

MATERIALS AND METHODS

Red drum and spotted seatrout populations were sampled from seven study areas along the Louisiana coast, and from one estuarine area in Texas. Most samples contained more than 40 individuals of each species. The study areas and the seasons in which they were sampled are indicated in Figure 1.

Louisiana study area 4 (Terrebonne Parish) was selected for more intensive temporal and microgeographic sampling. For this purpose, four subareas within this study area were established and sampled at approximately monthly intervals over the course of a year. The four subareas—Cocodrie, Moss Bay, Bay St. Elaine and Terrebonne Bay—are separated in a north-south direction by distances of 4, 9, and 7 km, respectively, and represent different salinity regimes ranging from relatively low at Cocodrie (<10 ppt) to relatively high at Terrebonne Bay (>25 ppt).

Fish were collected by both netting and angling. The majority of fish were taken in a 100-m variable mesh, monofilament gill net (stretched mesh size ranged from 2.5 to 13 cm), which was usually set in a semicircle from the shore, enclosing an area of approximately 0.1 hectares. The enclosed surface was then struck with oars to drive fish into the net. The effectiveness of such netting operations was evaluated on three occasions by blocking off the enclosed area after such "strikes" and using rotenone to ascertain the total numbers of unnetted red drum and spotted seatrout. These evaluations indicated that the netting procedures netted approximately 20% of the catchable red drum and spotted seatrout enclosed within the nets, and that the size distribution of catchable but unnetted fish was similar to that of fish taken in the variable mesh net. Although netting success varied widely during the course of the study, the average capture rate was close to two red drum and four spotted seatrout per set.

A total of 402 red drum and 614 spotted seatrout were obtained in the entire study. Fish were sexed, weighed to the nearest gram, and their standard lengths were measured to the nearest 0.1 cm. To linearize the relationship between weight (W) and standard length (SL), the regression model $\text{Log } W = \log a + b(\log SL)$ was fitted to weight/length data by sex and by coastal area. Analysis of covariance was used to test for differences between regressions.

Condition factors ($100\ W/SL^3$) of whole fish were calculated for all fish collected, tested for normality and averaged according to sex, season, and coastal study area. Effects of these variables were evaluated by Duncan's comparison-of-means test. Similar comparisons were made among mean condition factors of fish from the four subareas in Terrebonne Parish to establish any temporal and/or

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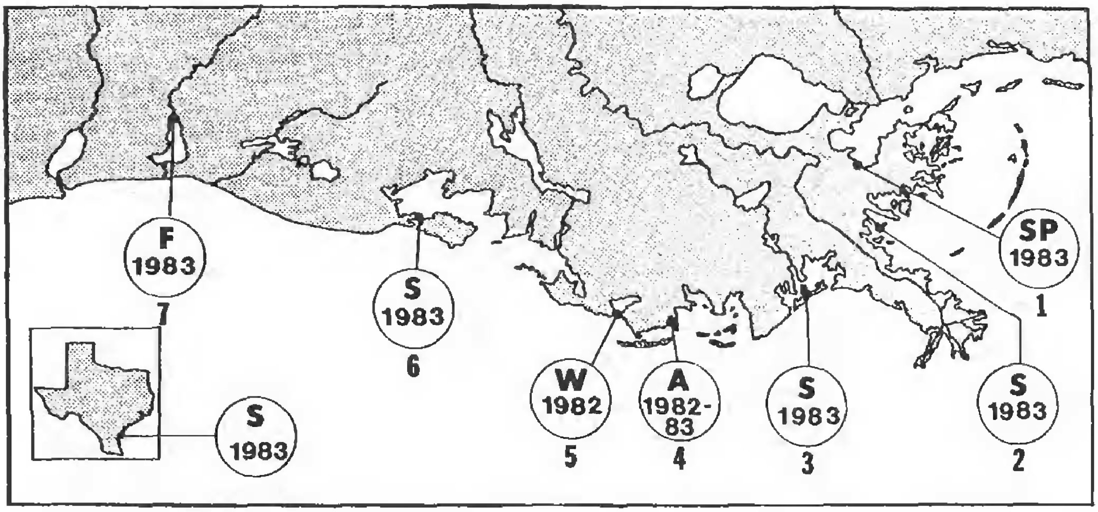

Figure 1. Sampling areas in Louisiana and in Texas (insert) with seasons when red drum and spotted seatrout were collected from each area (SP = spring, S = summer, F = fall, and A = all seasons).

microgeographic differences in condition factors for these species.

Age and growth were evaluated by two methods: (1) by seasonal and overall length-frequency analyses; and (2) by scale reading. For the latter, plastic scale impressions were prepared from scales taken from the shoulder region of each fish and examined with a microprojector. Standard scale-aging criteria (Lux 1971) and published criteria for the scale-aging of sciaenids (Schlossman and Chittenden 1981) were used to identify annuli.

Walford plots (Walford 1946) were fitted to obtain estimates of asymptotic standard length (L_∞) and growth coefficients (K) for red drum and spotted seatrout. These estimates were then used to fit von Bertalanffy growth equations for these species in Louisiana.

RESULTS AND DISCUSSION

Weight-Length Relationships

Analysis of covariance revealed no significant differences ($P>0.05$) between sexes for the slope or elevation of log weight regressed against log standard length for either species (red drum, F = 1.86; spotted seatrout, F = 2.25). For this reason, sexes were combined to obtain weight-length regression equations for Louisiana and Texas fish (Table 1). Predicted weights from the Louisiana equations for 30 cm (standard length) red drum and spotted seatrout were 509 g and 414 g, respectively, agreeing closely with Overstreet's (1983a, b) predictions of 511 g and 409 g for Mississippi red drum and spotted seatrout. However, because the majority of fish collected in this study were between 1 and 3 years of age, caution should be used in applying the equations to older or younger fish.

Condition Factors

Because the condition factor of fish (K_c) is often influenced by season, sex, maturity stage, and age, such parameters are important considerations when condition factors are compared (Everhart et al. 1975). In analyzing K_c values of fish collected in this study, the Kolmogorov-

TABLE 1

Regressions of weight (W) in g vs. standard length (SL) in cm for red drum (R) and spotted seatrout (S) collected from Louisiana and from Texas. The regression model is Log W = log a + b (log SL). N = number of fish.

State	Species	N	Log a	b	r^2	Predicted weight for 30 cm fish
LA	R	363	−1.4590	2.8203	.99	509 g
LA	S	561	−1.6664	2.8996	.98	414 g
TX	R	36	−1.6718	2.9516	.99	488 g
TX	S	54	−1.5719	2.8204	.97	393 g

TABLE 2

Seasonal condition factors ±SE of red drum and spotted seatrout. R = red drum; S = spotted seatrout; N = number of fish.

Species	Spring	(N)	Summer	(N)	Fall	(N)	Winter	(N)
R	1.83±.02	(53)	1.99±.01	(217)	1.85±.01	(130)		
S	1.63±.02	(51)	1.58±.01	(269)	1.51±.01	(266)	1.50±.06	(34)

Smirnov test statistic (D) was found to be less than the critical value of $D_{.05}$ for all collections. Thus, there was no reason to reject the hypothesis that this characteristic was distributed normally (Sokal and Rohlf 1969).

Analysis of variance revealed that the K_c values obtained in this study varied significantly with study area and with season, but not with sex. For this reason, sexes were combined to obtain average seasonal condition factors (Table 2) and mean condition factors for each estuarine study area (Table 3).

In both species, high condition factors appear to be associated with seasons immediately prior to spawning. Thus, red drum K_c values were highest in summer prior to the fall spawning period, while those of spotted seatrout were highest in spring immediately preceding their spawning period, which begins in late spring and continues throughout the summer.

The low variability for K_c values within each estuarine study area (Table 3) suggests that condition factors may be useful in comparing the relative well-being of subpopulations of these species, provided that the fish from each area are collected during the same season. Duncan's multiple range test indicated that red drum and spotted seatrout from the Port Aransas area of Texas (collected during summer 1983) were significantly ($p<0.05$) less robust than Louisiana fish collected during the same season (Table 3).

Analysis of condition factors of fish from coastal study area 4 revealed no significant differences between the four subareas sampled, indicating that the salinity regimes (low, <10 ppt; intermediate, 10–25 ppt; and high, >25 ppt) represented within this microgeographic range have little effect on the robustness of these euryhaline species. Condition factors for both species from study area 4 did, however, vary significantly with season, following the same seasonal trends shown in Table 2.

TABLE 3

Regional condition factors ±SE of red drum and spotted seatrout from Louisiana study areas 2–7 and from Texas.

Study Area	Red Drum		Spotted Seatrout	
	N	K_c	N	K_c
L2	(56)	2.05±.02	(64)	1.71±.02
L3	(49)	1.96±.02	(50)	1.35±.02
L4	(100)	1.94±.02	(296)	1.53±.01
L5	(43)	1.94±.02	(51)	1.49±.02
L6	(55)	2.04±.02	(54)	1.57±.01
L7	(11)	1.93±.04	(51)	1.61±.01
Texas	(37)	1.82±.02	(55)	1.41±.02

Length Frequencies, Age and Growth

Standard-length distribution (2-cm intervals) of all Louisiana red drum and spotted seatrout collected in this study are shown in Figure 2. Modes could be discerned in red drum length frequencies at 22 cm, 32 cm, 44 cm, and 56 cm. Comparison with other age-length information for red drum (Pearson 1929, Matlock 1984) indicates that these modes probably represent age classes I, II, III, and IV, respectively.

As might be expected in a species with an extended spawning period, age classes were not so clearly evident in length distributions of spotted seatrout. Nevertheless, apparent modes could be discerned at 10 cm, 26 cm, 34 cm, and 44 cm. Based on age-length data for spotted seatrout from the Gulf coast (Guest and Gunter 1958) and from the eastern U.S. coast (Mercer 1984), the latter three modes probably represent age classes II, III, and IV, respectively. It should be noted, however, that Pearson's (1929) back-calculated age-lengths for spotted seatrout indicate a slower growth rate than is indicated here, and if his estimates were followed these modes would more likely represent classes III through V.

Length frequencies during each season were also determined, and modes from these seasonal distributions were

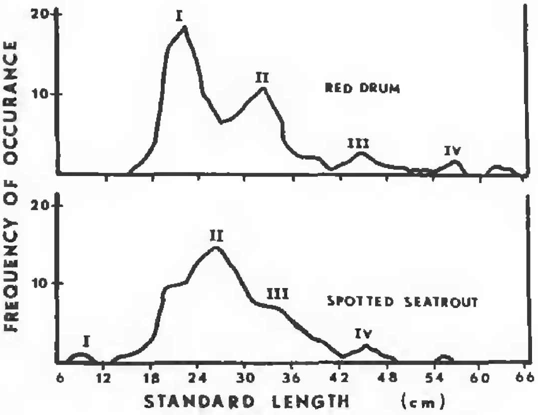

Figure 2. Length distribution of all Louisiana red drum and spotted seatrout collected in this study. Roman numerals indicate probable age class modes.

graphed to provide an indication of growth of each species during their first three years (Figure 3). The plots indicate red drum standard lengths to be 22 cm at age 1 and 38.5 cm at age 2, while the indicated standard lengths of spotted seatrout at these ages are 17.5 cm and 30 cm, respectively. The curvilinearity of the growth curves in Figure 3 suggests decreased growth rates in both species during winter.

Aging by scale analysis was hampered in both species by the presence of false annuli which were often difficult to distinguish from true annuli. Reading of red drum scales was further hindered by calcified deposits which tend to obliterate annuli as the fish grow. The consistency of our age determinations by scale reading was evaluated by randomly selecting 50 scale impressions of each species for reexamination. The second reading showed 76% agreement with the first reading for spotted seatrout, but only 32% for red drum.

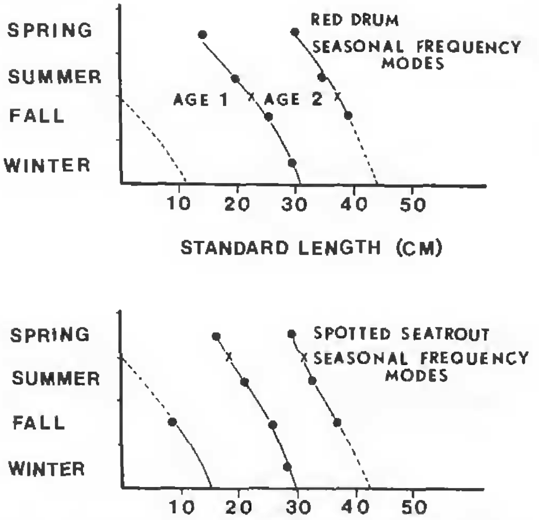

Figure 3. Yearly growth of red drum and spotted seatrout during their first three years as estimated from changes in seasonal length distribution modes. Closed circles indicate seasonal length distribution modes and dashed curves represent extrapolations of lines connecting the seasonal modes. Yearly increments from the y-intercept are represented by X.

Despite these inconsistencies, the mean lengths of each age class (as determined by number of annuli identified) were similar to the modal age-class lengths identified from length-frequency analysis (Table 4). Thus, scales can apparently be used to age spotted seatrout and red drum from Louisiana populations, but the procedure is difficult and time consuming.

Figure 4 shows Walford plots fitted to the year-end standard lengths for each species. The Walford equations for these plots are:

$$\text{red drum: } SL_{t+1} = 22 + 0.75\ SL_t$$

$$\text{spotted seatrout: } SL_{t+1} = 17.5 + 0.71\ SL_t$$

where SL_t and SL_{t+1} are standard lengths at ages t and t+1, respectively. Because the Walford plots are based on only two points, they should be used with caution. Moreover, growth of these species is probably not isometric over larger size ranges, so asymptotic weights estimated from these equations (Table 5) are probably underestimates. By comparison, Condrey et al. (1984) estimated an asymptotic length of 65.5 cm for Gulf coast spotted seatrout, while

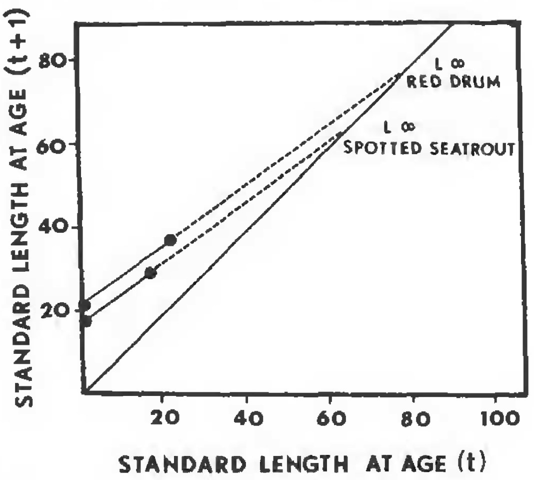

Figure 4. Walford's growth transformation for Louisiana red drum and spotted seatrout showing predicted asymptotic standard length (L_∞) for each species. Year-end standard lengths were obtained from Figure 3.

TABLE 4

Standard lengths (cm) of various age classes of red drum and spotted seatrout. MODAL LENGTH represents modes from standard length distributions in Figure 4. MEAN LENGTH (ANNULI) represents means of age groups identified by scale analysis. Estimated year-end lengths are from Figure 3.

	Spotted Seatrout				Red Drum			
AGE CLASS	I	II	III	IV	I	II	III	IV
MODAL LENGTH	–	26.0	34.0	44.0	22.0	32.0	44.0	56.0
MEAN LENGTH (ANNULI)	16.0	23.0	30.0	36.0	21.0	29.0	44.0	57.0
EST. YEAR-END LENGTH	17.5	30.0	–	–	22.0	38.5	–	–

TABLE 5

Von Bertalanffy equations for growth in length of red drum and spotted seatrout. Standard lengths (SL) in cm were derived from the von Bertalanffy equations with t_o assumed to be zero. Estimated weights were calculated from Louisiana weight-length regressions in Table 1. G_x = instantaneous growth coefficients.

	Red Drum			Spotted Seatrout		
Equation:	$l_t = 88.0\ (1-e^{-.2877(t+t_o)})$			$l_t = 61.2\ (1-e^{-.3864(t-t_o)})$		
	SL(cm)	W(g)	G_x	SL(cm)	W(g)	G_x
SL and W at age 1	22	210		17.5	87	
SL and W at age 2	38.5	1026	1.582	30.0	414	1.559
SL and W at age 3	50.9	2261	.790	38.9	879	0.753
SL and W at age 4	60.2	3635	.475	45.3	1366	0.441
SL and W at age 5	67.2	4941	.307	49.8	1798	0.275
Asymptotic SL & W	88.0	10593		61.3	3285	

Matlock (1984) estimated an asymptotic length of 106.5 cm for Texas red drum.

Despite some ongoing criticisms of its suitability (Knight 1968, Schnute 1981), the von Bertalanffy growth equation is still widely used in fisheries research, and its parameters are commonly implemented in yield-per-recruit analysis. For this reason, von Bertalanffy equations for growth in length were estimated from the Walford plots and tentatively used to project standard lengths for each species for ages 1 through 5 (Table 5). Predicted weights in Table 5 were obtained from the length-weight regressions for each species.

Yearly growth rates (G_x) were calculated from the predicted year-end weight of each age group. The equation for yearly growth rate is:

$$G_x = (\ln W_i - \ln W_{i-1})/t$$

where W_i is weight in grams at age i and t is time in years (Bagenal and Tesch 1978). Yearly G_x values for each species decreased with increased age (Table 5) following the usual pattern for growth in fishes (Paloheimo and Dickie 1966). The G_x values indicate that red drum and spotted seatrout in Louisiana both show rapid growth rates, particularly during their first two years when average daily weight increases are close to 0.4% of body weight.

Sex Ratios and Mortality Rates

Analysis of sex ratios of various age classes (t–test, α = 0.05) showed that red drum sex ratios did not differ significantly from 50:50 over the entire length range collected (16–85 cm, SL). However, as standard length of spotted seatrout increased, there was a marked increase in the proportion of females (Figure 5). No male seatrout over 40 cm SL were collected. Similar increases in the proportion of females with increased size have been previously noted in Mississippi (Overstreet 1983a) and Florida (Tabb 1961) populations of spotted seatrout.

Annual mortality rates of these species can be estimated from the age frequency data if the following assumptions are made (Rounsefell and Everhart 1953): (1) ages have been accurately deciphered; (2) natural and fishing mortality rates were uniform and constant during the time period covered by all age groups collected; (3) annual recruitment was constant over the time period represented by the sample; and (4) the age distribution of samples are representative of the true age distribution.

Although these assumptions could not be established with any degree of certainty, age frequencies from this study were used for preliminary estimations of total mortality for Louisiana populations of red drum and spotted seatrout. The method of Robson and Chapman (1961) was used to obtain estimates of the annual survival rate (s) and the instantaneous mortality coefficient (Z) for each species (Table 6). If male and female seatrout are considered separately, the estimated annual survival rate of female spotted seatrout (0.36) is approximately double that of males (0.16), a phenomenon which may have an important influence on the fishery. The estimated annual survival rate for red drum was also 0.16. Previous estimates of survival rates of these species tend to be somewhat higher than those obtained in this study. Tatum (1980) estimated annual survival for spotted seatrout populations in Alabama to be as high as 0.50, while Rutherford (1982) estimated an annual

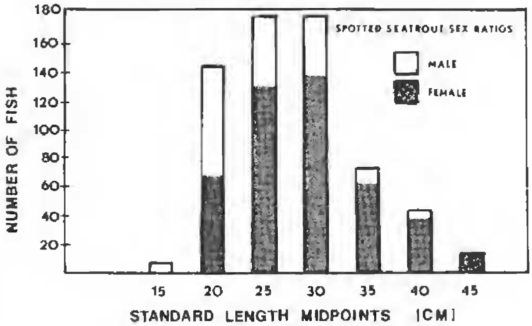

Figure 5. Changes in sex ratios of spotted seatrout with respect to body length.

TABLE 6

Annual survival rate (s) and instantaneous mortality coefficient (Z) for spotted seatrout and red drum as estimated from collected age frequencies. Postulated instantaneous fishing mortality coefficients (F) and instantaneous natural mortality coefficients (M) are based on the assumption that fishing mortality is 90% of total mortality (see text).

Species	s	Z	F	M
Spotted seatrout	0.32	1.139	1.025	0.114
Red drum	0.16	1.833	1.650	0.183

survival rate of about 0.25–0.30 for spotted seatrout in Everglades National Park. Matlock (1984) indicates an annual survival rate of 0.20 for Texas red drum populations.

We were unable to obtain estimates of fishing mortality rates versus natural mortality rates from our data. Natural mortality, however, tends to be relatively low in heavily exploited fish species, with fishing mortality usually comprising 85–90% of total mortality after such fishes attain vulnerable age (Rounsefell and Everhart 1953). Pauly's (1980) analysis of interrelationships between natural mortality, growth, and mean environmental temperature in 175 fish stocks also indicates that, for rapidly growing, long-lived species at temperatures characteristic of the Louisiana coast, natural mortality might be expected to be relatively low compared with fishing mortality. For this reason, the postulated instantaneous coefficients for fishing mortality (F) and natural mortality (M) of red drum and spotted seatrout in Louisiana (Table 6) are based on the assumption that mortality due to fishing is approximately 90% of total mortality in these species.

Population Numbers and Densities

If an estimate of the annual catch (C) is available, the annual fishing mortality rate (f) can be used to obtain an estimate of the total number of fish of vulnerable size in a population. The appropriate equation is $N = C/f$, where our postulated value for f is $0.9\,(1-s)$.

Approximately 450 thousand kg of red drum and 600 thousand kg of spotted seatrout are taken annually from Louisiana waters by commercial fishermen (Adkins et al. 1979, Perret et al. 1980). Since the recreational/commercial fishing ratio for both species has been estimated to be about 90:1 (Adkins et al. 1979), the total yearly harvest in Louisiana is about 40 million kg of red drum and about 55 million kg of spotted seatrout. Dividing these biomass values by the mass of the average fish taken in this study, we obtained the following estimates of total catch (C) for each species:

red drum: C = 40 million kg/0.525 kg = 76 million
spotted seatrout: C = 55 million kg/0.385 kg = 143 million.

Inserting these values into the equation, $N = C/f$, the following preliminary estimates of total number of fish of vulnerable age in Louisiana waters were obtained:

red drum: N = 76 million/0.756 = 100.5 million
spotted seatrout: N = 143 million/0.612 = 233.7 million.

It is important to note that these population estimates are conservative since they are based on the assumption that fishing mortality is relatively high compared to natural mortality for these species in Louisiana. If fishing mortality is low for these species, as was suggested by Iversen and Moffet (1962), population estimates would be almost an order of magnitude greater.

Barrett (1970) calculated the total water area of coastal Louisiana to be 1.376 million hectares. Thus, the expected average densities based on our preliminary estimates of population numbers in Louisiana are:

red drum: 100.5/1.376 = 73.5 individuals per hectare, and
spotted seatrout: 233.7/1.376 = 169.8 individuals per hectare.

A 100-m net, such as was used to collect fish in this study, encloses an area of approximately 0.1 hectare when set in a semicircle from the shore. If many such sets are made, the average number of fish enclosed in each set should include about 7 red drum and about 17 spotted seatrout. Because our rotenone studies indicated that this netting procedure captures approximately 20% of the vulnerable-sized fish enclosed, an *average* set should capture 1.5 red drum and 3.4 spotted seatrout. These estimates are very close to our overall stratified sampling capture averages

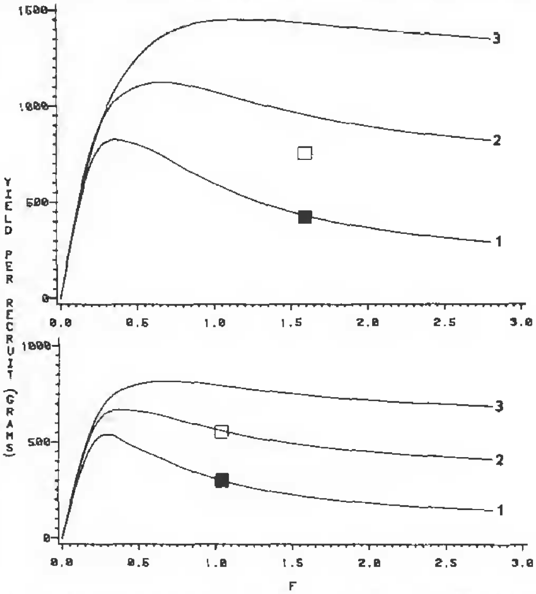

Figure 6. Yield curves (with t_c = 1, 2, and 3) as a function of F for red drum (top) and spotted seatrout (bottom). The closed squares indicate the current estimated position of the Louisiana fishery and the open squares indicate the estimated position if standard length at first capture were set at 30 cm.

from many sets at many diverse locations throughout the coastal region of Louisiana, an observation which tends to support our population estimates for these species.

Yield-per-Recruit Estimates

Beverton and Holt's (1966) tables of yield functions provide isopleths of yield per recruit as a function of size at first capture and exploitation rate for a series of values of M/K ranging from 0.25 to 5.0. Using the estimated M/K values from the present study (M/K = 0.35 for spotted seatrout; M/K = 0.64 for red drum), and assuming the size at first capture to be 20 cm (no minimum recreational size limits for either species in Louisiana), the tables indicate yields of about 0.4 kg/recruit for red drum and about 0.3 kg/recruit for spotted seatrout when the exploitation rate is 0.9.

The Beverton-Holt (1966) model is particularly useful for assessing effects of changes in fishing effort or in size of first capture (Gulland 1969). The effect of increasing the size of first capture is graphically illustrated in Figure 6 in which yield-per-recruit curves as a function of the fishing mortality coefficient (F) are shown for various ages at first capture (t_c). The curves indicate that yield per recruit for red drum and spotted seatrout in Louisiana would be almost doubled by increasing the length at first capture to 30 cm (SL). By contrast, if the recreational/commercial fishing ratio for these species is about 90:1 (Adkins et al. 1979), a ban on commercial fishing would have minimal effects on yield per recruit.

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